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ENERGY CONSERVATION, NEW AND RENEWABLE SOURCES OF ENERGY

The Prospects for Incineration of Municipal Solid Waste in Russia in Order to Produce Heat and Electric Power

A. P. Baskakov
Ural Federal University, ul. Mira 19, Yekaterinburg, 620002 Russia
e-mail: baskakov_ap@e1.ru

Abstract—The article presents the results of the low-temperature pyrolysis of the main components of municipal solid waste (MSW): wood, products of wood processing (paper, cardboard, fabrics, etc.), various plastics, rubber, as well as of a representative sample of MSW. A waste-to-energy plant is described, at which municipal solid waste is subjected to the pyrolysis, and then pyrolysis products are incinerated in a slagging-bottom furnace. The paper presents an analysis of the operation of a modern waste-to-energy plant equipped with a wet scrubber, with a high-degree recovery of the heat of exhaust gases by means of a heat pump, and with evaporation cooling of glowing slag in a tank filled with water. Chemical treatment of water circulating in the system makes it possible to convert heavy metals and other hazardous substances into the insoluble form and then to remove them.

Keywords: municipal solid waste, waste-to-energy plants, pyrolysis, cleaning of gaseous combustion products, heavy metals, waste incineration

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In many countries with the high density of population, in which there is lack of areas for landfill sites, disposal of unsorted municipal solid wastes (MSWs) in dumps and landfill sites is limited. The problem of a lack of such sites is acute in Russia as well. In Germany a law has been adopted according to which only those materials that contain no more than 5% of organic substances may be disposed in landfills.

An alternative to disposal of MSW in landfills is the implementation of thermal methods, first and foremost, the use of MSW as fuel with generation of electric power and heat for district heat supply. In 2011, in Europe alone there were in operation more than 450 facilities incinerating MSW, most of them—with a supply of thermal and/or electric energy to end users [1]. In the Soviet Union, 14 plants for incinerating MSW were constructed, some of which were dismantled in the 1980s because they did not meet the environmental requirements. In Europe at about the same time there were some refuse-burning plants closed down for reconstruction because of impermissibly high emissions of hazardous substances together with gaseous combustion products. Along with nitrogen oxides, hydrochloric acid vapor, mercury, and other heavy metals, the most hazardous are dioxins and furans—supertoxical substances that move freely through food chains "plants–animals (fish)–man," damage the immune system, and affect the liver and the central nervous system, i.e., in fact, all organs of man and animals. The concentration of dioxins and furans in MSW (reduced to the concentration of the most hazardous of these compounds) is 50 ng/kg [2], while their maximum allowable concentration in combustion products is 0.1 ng/m^3 [2].

Despite such stringent environmental requirements, up to the present, the "dioxin problem" may be thought of as having already been solved. Like any organic substance, dioxins and furans burn in a furnace at a high temperature and a sufficient concentration of oxygen. A standard of the European Union [3] requires that combustion products should remain in a furnace or a gas duct at a temperature of at least 850°C for at least 2 s with an oxygen content in them at least 6% (by volume). However, when there are benzene-like compounds and chlorine in combustion products, dioxins may be again formed in the oxidizing medium at temperatures ranging from 250 to 500°C (so-called secondary dioxins that are trapped in the gas-cleaning system).

Figure 1 shows the simplified schematic diagram of Moscow specialized plant (MSP) no. 2, which was commissioned in 2002 after fundamental reconstruction. Other Russian modern facilities for thermal treatment of MSWs are described in [4–6]. It should be emphasized that at these facilities the concentration of hazardous substances in gaseous combustion products meets the most stringent European requirements.

In the opinion of many specialists, not only gaseous emissions, but also ash containing heavy metals, dioxins adsorbed by ash particles, and other hazardous substances present a severe environmental hazard. Therefore, for example, in Germany, ash and slag

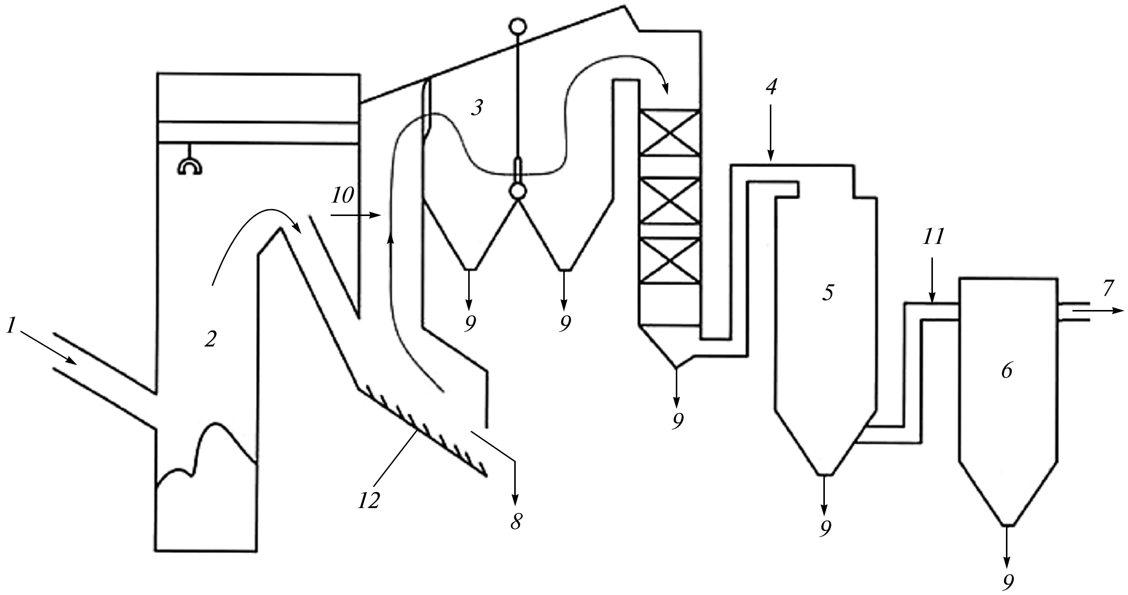

Fig. 1. Schematic process circuit of the Moscow Special Plant No. 1 for incinerating MSW without subjecting it to classification. (*1*) MSW from containers; (*2*) receiving bin; (*3*) steam boiler; (*4*) injection of lime milk; (*5*) absorber; (*6*) bag filter; (*7*) combustion products to the smoke exhauster and to the chimney stack; (*8*) slag; (*9*) ash; (*10*) injection of carbamide solution; (*11*) injection of activated carbon; and (*12*) furnace with a sloping reciprocating grate.

from garbage-burning plants must be disposed of in idle mines and other underground cavities.

In burning MSW, unlike that of the most power-plant fuels, a large amount of chlorine can be released, which passes into the combustion products mainly in the form of hydrochloric acid vapor (150–350 mg/m^3) and other chlorides. At the temperature of metal higher than 400°C chlorides cause its strong corrosion.

One of the recently developed methods of corrosion protection is application of a dense ceramic layer with the porosity of less than 1% to the pipes; this layer prevents the contact between chlorine-containing particles and metal [7]. The thickness of such a ceramic coating usually is from 75 to 90 μm.

Sorting of waste prior to its incineration, with the removal of chlorine-containing products, mainly polychlorvynil, may serve as another method of protection from chlorine-hydrogen corrosion. In the last decade in the world there has been a strive to use MSW as a source of raw materials for their reprocessing.

In Russia, sorting of MSW (extraction of secondary raw materials) is mainly carried out manually. Abroad, and in recent years in Russia as well, automatic (rather, semi-automatic) lines with the use of computer technologies in combination with infrared and X-ray detectors (Fig. 2) are under development [8]. Such a method is especially attractive for polymer sorting for the following reasons. First, their mass fraction in MSW increases progressively: the averaging over several large cities showed that it has increased from 5% in 1994 to 12–15% in 2010 and still continues to increase [9]. Second, each type of polymer has a commodity value, if it has been isolated in the pure state, which makes manual sorting more difficult because of the diversity of these polymers.

On the semi-automatic line, from the spectral composition of radiation reflected from an object, which moves on the conveyor, a type of polymer is determined, and its image is transmitted to the discharger installed at the end of the conveyor. In the discharger, by means of the air jet produced at the required instant of time, the sorted polymer is dropped ("shot off") into an appropriated container. Infrared radiation cannot give any idea whatsoever of the chemical composition of an object. But the content of elements, in particular, chlorine, is determined by means of X-ray radiation [8]; however, in this case an object being scanned should not be thinner, at least, than 1 mm. The installation of an electromagnetic transducer allows one to identify and, correspondingly, to trap electrically conducting components as well.

The most economically sound method is the semi-automatic sorting, when plastic films are removed manually at the outset of the waste sorting process, and then various types of plastics are isolated automatically by means of infrared radiation detectors. With manual sorting, 65% of plastics contained in the flow of MSW are "selected," with semi-automatic sorting, 80% of them are withdrawn, and with automatic sorting, 77% of them are withdrawn.

It should be noted that even with the most advanced sorting of MSW, no less than one half of it is

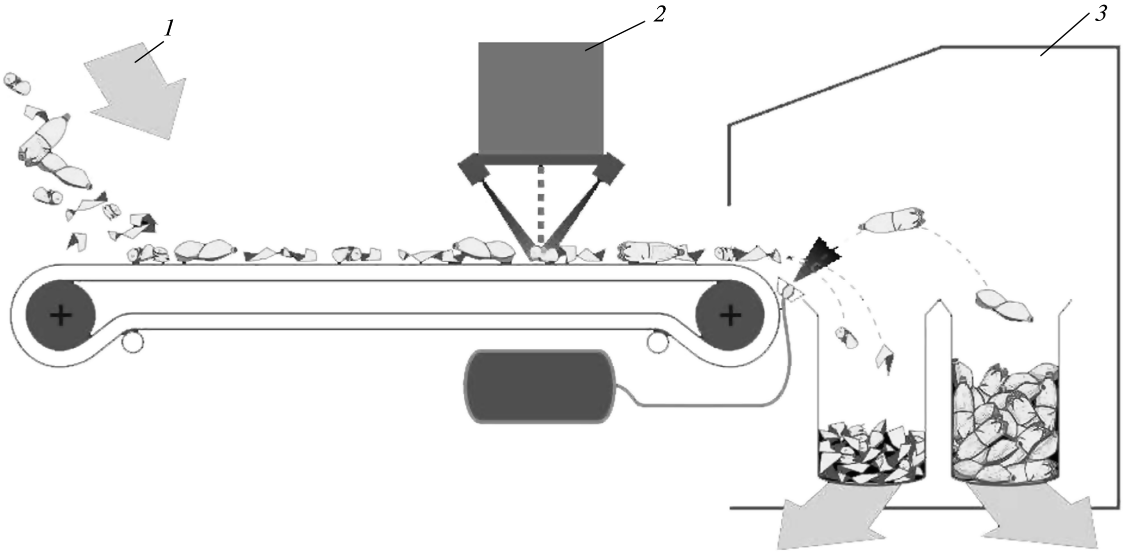

Fig. 2. Sorting of MSW by means of scanning in the near-infrared region. (*1*) MSW from container; (*2*) infrared radiation detector; (*3*) discharger.

"trash" containing more than 5% organic substances, which then must be thermally processed. The main thermal methods of their processing are pyrolysis, gasification, or combustion.

As of today, inflammable gas produced in gasifiers cannot compete with natural gas. Apparently, not a single gasifier is in Russia. Therefore, gasification is not discussed in this paper.

"Pyrolysis of organic substances" usually means their decomposition when heated without air access. MSW contains two groups of substances which can be pyrolysed—plastics and so-called lignocellulose components: food waste, paper, cardboard, fabrics, wood, etc. The chemical composition of these components is close to that of cellulose and lignin—the main components of wood. Wood pyrolysis has been investigated most thoroughly in the first half of the last century in connection with obtaining charcoal and other products [10]. In recent years interest has again developed in the low-temperature pyrolysis ("torrefaction') of wood waste and even grass for the purpose of producing improved (mainly household) fuel.

The intense decomposition of wood on its charring begins at the temperature from 280 to 290°C and occurs with heat release. The mass of the solid residue, its elemental composition, high calorific value relative to its mass, and the mass of initial wood are given in table [10].

With an increase in the temperature above 350°C (in the present paper the table is given in an abridged form) the wood decomposition still continues, but now slower, and at the temperature of 900°C the mass of solid residue is 26.6%. At the charring temperature of 400°C the yield of products of the pyrogenic decomposition of birch, pin, and fir (in percent of the mass of absolutely dry wood) is the following: coal—from 33.7 to 37.4%, gaseous substances—about 17%, and liquid substances—from 45.4 to 48.3%. It is very important to emphasize that decomposition reactions are exothermal ones; therefore, on the subsequent

The changes in the wood composition in the course of its charring

Charring temperature, °C	Mass of solid residue, %	Residue composition, %			Q_s^r, MJ/kg	Calorific value per 1 kg of initial wood, kJ/kg
		C	H	O		
100	100.00	47.41	6.54	46.05	19.9	19.9
200	92.60	55.40	6.12	38.48	20.8	19.3
280	78.50	58.14	6.02	35.84	24.5	19.2
300	53.60	72.36	5.38	22.26	26.7	15.5
350	46.80	73.90	5.11	20.99	31.2	12.8

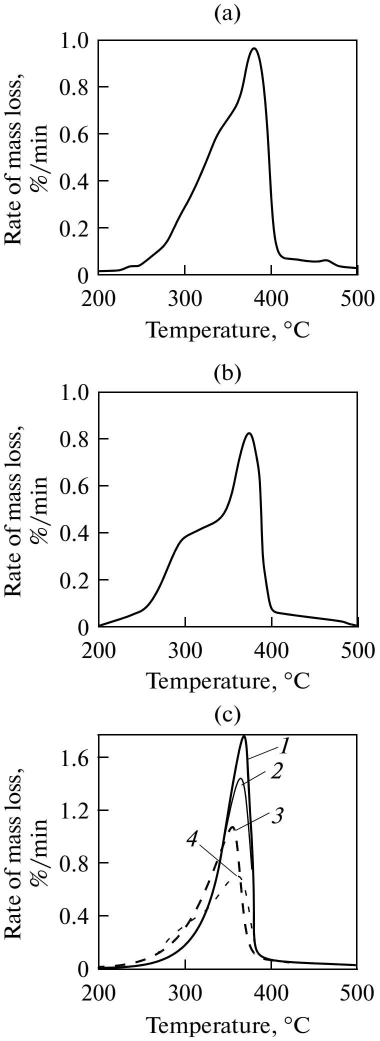

Fig. 3. The differential thermogravimetric curves of decomposition of coniferous (a), deciduous (b) trees, and products of wood processing (c): (*1*) lavatory paper; (*2*) office paper; (*3*) card-board; (*4*) wood wastes.

combustion of solid residue less heat will be received than on the combusting of initial wood.

It can be seen from Fig. 3 that the thermogravimetric curves of different wood species (Figs. 3a, 3b) and those of products of wood processing are practically the same.

Cotton consists almost entirely of cellulose. The maximum of its differential thermogravimetric curve corresponds to the temperature of 338°C. The destruction process begins at the temperature of 165°C. After 400°C the rate of mass loss is insignificant, and the pyrolysis residue decreases from about 25% at 400°C to 20% at 650°C. The solid residue contains about 15.8% of carbon and 1.8% of ash. Pyrolysis of newsprint paper begins at 175°C, and the maximum decomposition rate is observed at 338°C. The mass of solid residue at 400°C is 30%, while at 647°C it is 23.1%. The ash content of residue is 5.9%.

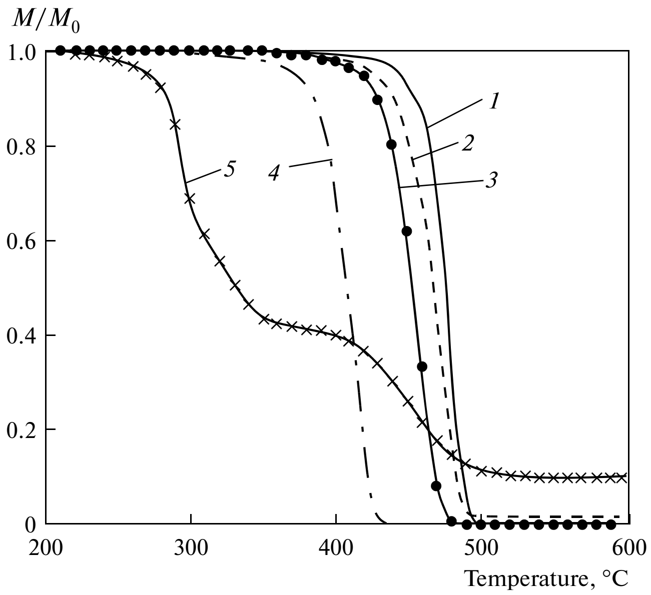

Fig. 4. The integral thermogravimetric curves of most widely used plastics [12] (a full non-decomposed residue depending on a temperature): (*1*) and (*2*) high- and low-pressure polyethylene, (*3*) polypropylene, (*4*) polystyrene, and (*5*) polyvinylchloride (PVC).

From the above discussion it follows that thermal decomposition of all lignocellulose components begins at the temperature of higher than 250°C and is practically over at 400°C. Only the amount and compositions of the solid residues differ (not very substantially).

Plastics are more stable than lignocellulose materials. It can be seen from Fig. 4 [12] that the most widely used plastics, except for polyvinylchloride (PVC), begin to decompose at temperatures from 350 to 400°C, and at 500°C, they decompose practically without the solid residue. The sole exception is fluoroplastic decomposition of which begins at 500°C and ends (without the solid residue) at 610°C. Polyvinylchloride, the second most important type of synthetic polymer used in a household, begins to decompose at 250°C, and the solid residue is about 10% even at the temperature above 500°C.

Unlike lignocellulose materials, plastics melt before their decomposition begins. The melting temperature of low-density polyethylene is from 105 to 108°C, that of high-density polyethylene, from 125 to 132°C, of polypropylene, from 164 to 170°C, of fluoroplastics, from 210 to 215°C.

Rubber products, in particular, tires, begin to decompose at 280°C. The mass loss at 480°C is about 60%, and with further increase in temperature the mass of the solid residue consisting of carbon black and ash, hardly decreases.

In accordance with thermogravimetric curves for various components of MSW discussed above, decomposition of an average sample of MSW (Fig. 5) begins at about 200°C and is over mainly at 500°C; at this temperature the mass of the solid residue is about 36%, while at 650°C, it is 30%. Thus, for the thermal treatment of MSW using the pyrolysis process the temperature range from 450 to 550°C is optimal.

According to the data published in [13], the yield of gas as a result of the pyrolysis of sorted municipal refuse at the temperature of 480°C is 12.33%, the yield of liquids (including water) is 61.08%, and the pyrolysis residue is 27.71%. The pyrolysis liquid contains about 50% of water [12].

In the literature there have been described many plants for waste pyrolysis and they can be fundamentally subdivided into two types: plants for waste pyrolysis with the aim of producing a flammable gas (sometimes, synthesis gas) and/or liquid fuel, and plants with the pyrolysis as a first stage of combustion. Plants of the first type may turn out to be advisable in certain specific cases, which are not considered here. Apparently, they are unsuitable for the pyrolysis of MSW. Gas and liquid fuel are ultimately used for subsequent combustion; therefore, the incineration of MSW with producing heat and electrical power seems to be a more simple solution. However, it is unlikely that obtaining high-value products by means of synthesis of gas or rectification of fluid will be profitable at relatively low consumption of the initial raw materials (MSW); nevertheless, in a pyrolysis plant, the solid residual must be incinerated (at least, for producing heat needed for the pyrolysis), i.e., also in this case the problem of incineration is not removed.

In many suggested and implemented schemes the pyrolysis of MSW without air access is used before the combustion (Fig. 6). It has been reported in [14] that in 2000, according to this scheme, the Mitsui company (Japan) constructed a plant to incinerate 70000 tons of MSW per year. Crushed MSW is subjected to drying and pyrolysis in a drum at the temperature of 450°C for 1 h. The drum is heated from outside by hot air. The pyrolysis gas is fed directly to the high-temperature furnace, while the solid residue consisting of coal char, inert substances, and metal, is cooled, then sieved, after which ferrous metal (by means of a magnetic separator) and aluminum (by means of the electrodynamic separator) are removed from it. Metals that have been heated at the temperature of 450°C in the oxygen-free medium are in a good marketable state. Remaining solid particles are ground and conveyed to the same high-temperature cyclone furnace in which the temperature of 1300°C is maintained. Ash particles are thrown to the furnace wall screens, melt, and flow down in the form of fluid slag, which is then granulated in the water tank. As a result, the glassy material is formed that can be used in the construction industry. The combustion products are cooled in the air heater to 600°C after which they enter into the waste heat recovery boiler that generates steam with the pressure of 4.0 MPa and the temperature of 400°C. The turbine generator with the capacity of 1.95 MW generates electricity for plant use and supplies 1 MW to the electric grid. Gases that leave the boiler at the temperature of 170°C enter into fabric filter no. 1 in which fly ash is captured, and then to filter no. 2, upstream of which lime used for HCl and SO_x fixation is injected into the gas flow in the form of dust. Only particles captured by filter no. 2, which come to merely 2% of the volume of raw MSW, are disposed to a dump. Fly ash from filter no. 1 is returned, as fly ash settled in the boiler flue gas ducts, to the furnace in which they melt and become glassy slag when granulated.

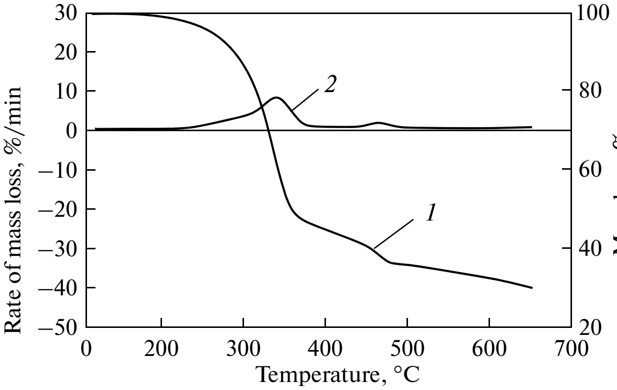

Fig. 5. The integral and differential thermogravimetric curves of the mass loss of a dry averaged sample of municipal waste at the rate of its heating equal to 10°C/min [12]: (*1*) mass decrease, %, and (*2*) rate of mass decrease, %/min.

The morphological and elemental composition of MSW are not given in [14]. In Japan, according to the data published in the same article, the collection of individual components of MSW from the population is well organized. Apparently, this scheme indeed operates using some types of waste. However, as it regards MSW having an "average" Russian composition, many questions arise. In the first place, it is not explained what the pyrolysis is necessary for at all. Extraction of metal being in a good marketable state is, of course, a side effect. The main objective is to obtain the high temperature in the furnace prior to organizing the reliable liquid slag removal, which is impossible in the case of direct (without the pyrolysis) incineration of MSW.

The mass of the solid residue after pyrolysis of even ash-free lignocellulose materials (wood) at 450°C does not exceed 50% of the initial mass, and after the pyrolysis of plastics (except PVC), it is very small. The ash content of MSW formed in Russia which are incinerated, for example, at the Moscow specialized garbage-burning plant no. 4, is A^r = 34–42% per as-received mass, at the humidity of W^r = 28–37% [15].

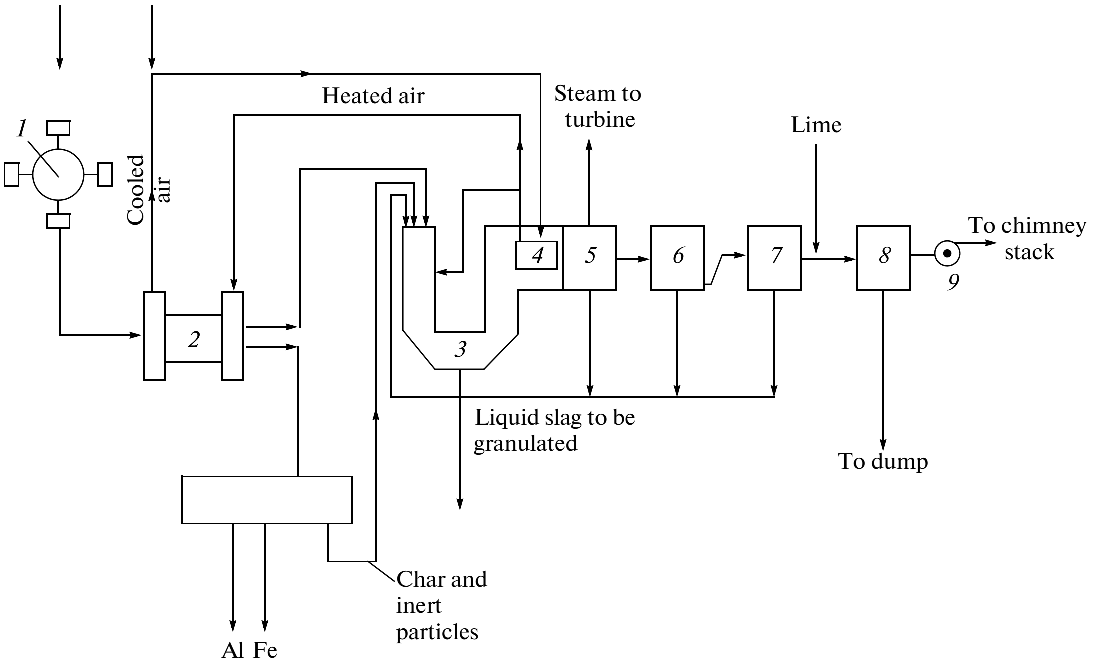

Fig. 6. A schematic diagram of the incineration of MSW with slag-tap removal.
(*1*) crusher; (*2*) drum for drying and pyrolysis; (*3*) cyclone furnace: (*4*) high-temperature air heater; (*5*) steam boiler; (*6*) economizer; (*7*, *8*) fabric filters; and (*9*) smoke exhauster.

The share of ash removed in the form of slag from a slagging wet-bottom furnace, is usually about 50% (in power-plant cyclone furnaces this percentage is higher, but it seems doubtful that such a design might be implemented at a garbage-firing plant). Given that ash captured in the ash collector returns again to the furnace (see Fig. 6), it is necessary to increase twofold the mass of ash entering into the furnace with each kilogram of MSW. All this ash must be molten by means of combustion of the pyrolysis residue, the content of combustible substances in which, in the best case, is one half of its content in raw MSW. The calculations showed that the heat released upon combustion is insufficient. Experience in combusting lignites with the ash content from 39 to 43% in cyclone furnaces, for example, in a furnace designed in the All-Russian Thermal Engineering Research Institute is known, but in these furnaces it is not crushed residue, as in the scheme shown in Fig. 6, but rather coal dust is fired.

From the above discussion it follows that it is not feasible to implement the preliminary (prior to incineration) pyrolysis of MSW (at least formed in Russia) and the separate combustion of the solid residue in a high-temperature region with liquid slag removal, while combustion of gaseous/vaporous pyrolysis products occurs in the region with more moderate temperatures. For some waste, instead of pyrolysis, it is necessary perhaps, to carry out drying with heating to the temperature no higher than 200°C, i.e., to implement the so-called open drying scheme which, by the way, is used for firing brown coals in a cyclone furnace. However, for municipal solid waste having the composition mentioned above, this scheme would not provide obtaining of the required temperature in the furnace.

The temperature in the furnace—1300°C, given in [14], seems insufficient to produce fluid slag. In power-plant furnaces with liquid slag removal the temperature of gases passing over the melt is from 1500 to 1700°C.

Removal of heavy metals, which will not be leached from a granulated material, is often spoken of as one of the advantages of using liquid slag removal in boilers intended for incinerating MSW [16]. However, this is not unambiguous. At high temperatures required for producing liquid slag, compounds that contain heavy metals are sublimated according to their partial pressures and are entrained by the gas flow. On cooling of the latter, these compounds settle on minute (micron) dust particles, which are poorly captured by filters and emitted into the atmosphere. With increasing temperature in the furnace the concentration of nitrogen oxides NO_x in combustion products increases. It is well known that at the temperatures as high as about 1400°C nitrogen oxides are formed from nitrogen contained in fuel (either solid or liquid). At a higher temperature the thermodynamic equilibrium of the reaction of oxidation of atmospheric nitrogen $0.5O_2 + 0.5N_2 = NO$ shifts markedly rightward, and the rate constant of this reaction increases. This is one of the reasons for which slagging bottom furnaces, in particular, cyclone ones, which were widely used in the power industry in the 1940–1950s, were practically stopped being built in the 1970s, when the concentration of NO_x in escaping combustion products at thermal power plants became regulated.

In this connection, practically at all modern municipal waste-incinerating plants dry-bottom boilers have been installed downstream of which the multistage gas-cleaning system is arranged. One such plant is, for example, the plant in Goeteborg (Sweden) that was reconstructed as far back as in the mid-1990s, after the environmental requirements to gas emissions were tightened (Fig. 7) [17].

MSW is brought to this plant by garbage trucks, then, waste is fed from the hopper to the furnace with a sloping reciprocating grate. The primary air is taken from the room for this hopper (as a result, a small rarefaction is formed there) and is heated by means of extracted steam to 130°C. According to the observations made by the author, there are no smells whatsoever either in the plant premises or in the building. The cleanliness in the building is the same as in a typical boiler room firing gaseous fuel. The secondary air is taken from the room in which the ash hopper is installed, and is fed while cold. With this secondary air, vapor also enters the furnace, formed at the evaporative cooling of slag.

Slag is cooled in the hopper by water and unloaded from it by the conveyor. The volume of slag accounts for 5% of the volume of arriving waste, and its mass accounts for 20% of the latter. In order to reduce the concentration of nitrogen oxides, 20% of the combustion products with the temperature of 230°C are returned to the furnace. For the same purpose ammonia is injected into the furnace. From the latter the combustion products are admitted to the steam boiler in which steam is heated to 400°C. To fully clean the combustion products from gaseous harmful substances, ash, and heavy metals which, as mentioned above, are adsorbed by the finest ash particles, gas is fed to the "wet" gas-cleaning plant. This plant operates as a closed water supply system, and hence, strictly speaking, not water but a solution of acids circulates through it; that is why all pipelines and apparatuses of this system (including pumps) are made of polypropylene and glass-reinforced plastics.

In the first stage of preliminary cooling ("precooler") of gases the exit gases are cooled by means of injection of water in the form of very small droplets (spray water) from the condensation-type cooler. The second stage of the precooler is the packed column. The value of pH of water circulating in both stages is 0.5. The exit gases are cooled in the precooler to 60°C, then they are fed to the condensation-type cooler (the packed column), in which their temperature drops to 40°C. As this takes place, more than 69% of water vapor contained in combustion products are condensed (at the inlet the concentration of water vapor by volume is 16–18%). The heat of water heated in the packed scrubber to 42°C is used in the absorption heat pump for heating the return water in the district heating system from 50 to 70°C, while cooled and dried combustion products are heated from 40 to 90°C by the extraction steam, and then emitted into the atmosphere through the chimney stack. The latter is made of corton steel.

The use of the heat pump makes it possible not only to utilize low-temperature heat that is released on condensation of vapor contained in exit gases, but also to organize the closed water supply system with minimum discharge of cleaned water into the river.

As a result of wet gas cleaning, all heavy metals, mercury vapor, hydrocloric acid, and other hazardous substances enter into water. The water treatment system is designed to render them harmless. At $pH = 0.5$ heavy metals react with acids in water. In the neutralizer $CaCO_3$ is added to the water, which increases the value of pH from 0.5 to 1.5. Into the decarbonator NaOH, $Ca(OH)_2$, and coagulant are injected; CO_2 being released is emitted into the atmosphere. Then, this water with $pH = 10.5$ is fed into the rectifying ammonia column. The matter is that water contains ammonia, which is injected into the furnace in order to reduce the concentration of NO_x, and the remainder of which is solved in the condensate when combustion products are cooled in the condensing-type cooler. In the column ammonia is released from water when steam is fed to the latter upwards, and is again admitted into the furnace. Thereafter, water enters neutralizer no. 1 in which the value of pH is brought to 8.5 by means of an addition of $Ca(OH)_2$ and HCl. Here, coagulant and organic sulfides are also injected, which fix contaminants and turn them into practically insoluble compounds.

From the settling tank, upstream of which coagulant is injected into water, the deposit that contains hazardous substances in the insoluble form is removed in the form of sludge that is mixed beforehand with fly ash from the electrostatic precipitator in order to facilitate its hauling. Water that has been additionally cleaned from impurities in the sand filter meets the requirements to the quality of potable water, but it has a rather high salt content (8 g/L); it is discharged into the river.

The plant in Goeteborg (Sweden) generates 170 GW h of electric power per year. Of this amount, 1/3 are used at the plant, while 2/3 are supplied to the electric grid. At the same time the plant provides the heat supply of one of the town districts, by producing 1000 GW h of thermal energy per year.

The improvement of boiler units and the gas-cleaning system (for example, the use of fabric filters instead of electrostatic precipitators) offered considerable reduction in capital and, first of all, operating costs. As a result, in Europe, and in Sweden, plants for incineration of MSW have become widely used, and, apparently, they are economically sound. According to the data published in [18], in this country 96% of MSW is recycled. Sweden even purchases MSW in neighboring

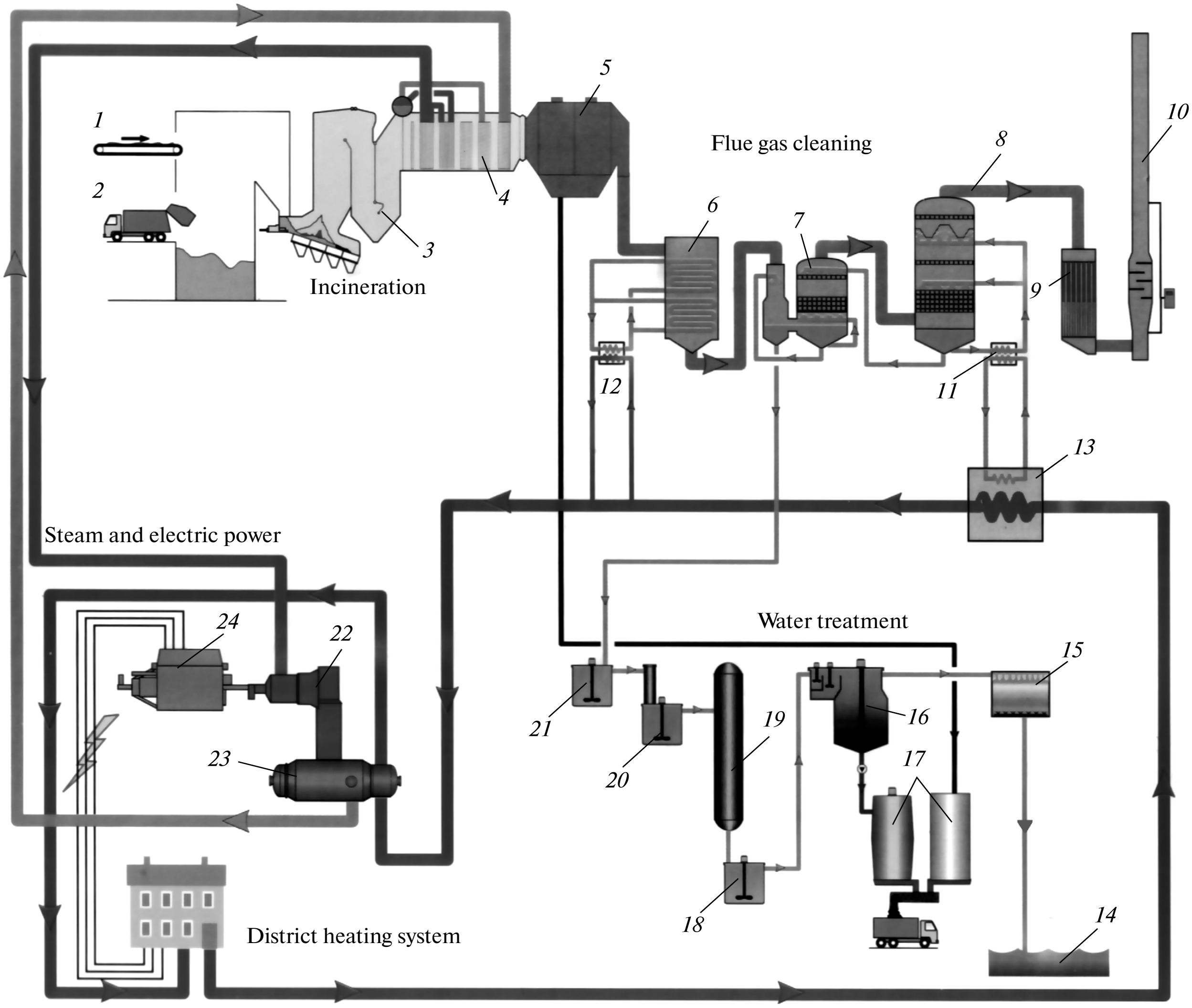

Fig. 7. A schematic diagram of the waste incineration plant in Goeteborg. (*1*) Separation of unsorted waste; (*2*) unloading of municipal waste after it has been collected separately by inhabitants; (*3*) furnace with a sloping reciprocating grate; (*4*) steam boiler; (*5*) electrostatic precipitator; (*6*) economizer; (*7*) precooler; (*8*) condensation-type cooler; (*9*) heating of exit gases; (*10*) chimney stack with a muffler; (*11*) heat exchanger of the heat pump; (*12*) heat exchanger of the economizer; (*13*) heat pump; (*14*) treated water discharged to the river; (*15*) sand filter; (*16*) settling tank; (*17*) tanks for slag and ash; (*18*) neutralizer no. 1; (*19*) ammonia column; (*20*) decarbonator; (*21*) neutralizer no. 2; (*22*) steam turbine; (*23*) network water heater; and (*24*) electric generator.

countries for producing fuel in return for electric power. It is of interest that, according to the interstate agreement, solid waste formed as a result of incineration shall be brought back to the country that sold MSW [18].

In conclusion, it might be good to point out one detail that has nothing in common with technical issues. In front of the entrance to the plant located in the town of Chiba (Japan) an enormous monitor is installed, which displays the information on the concentration of hazardous substances at the stack outlet at each specific instant of time. Moreover, visits to the plant are arranged regularly (mainly for schoolchildren), and they begin with the showing of an animated cartoon, which explains in a comprehensive way the necessity for separate collection of garbage (it has been well organized in Japan), its utilization, and harmonious coexistence of nature and man. If only at least one such plant was built in Russia, the population, and officials too, would better understand the purposefulness of constructing such facilities.

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